Anesthesia Machine

The Anesthesia Machine

- You are the master of the machine
- You are responsible for checking the machine prior to each case

The Anesthesia Machine (con't)

- The primary cause of machine malfunction is failure to check
- Never start without the American Express items

What is the function of the anesthesia machine?

Functions of the Machine

- Convert supply gases from high pressure to low pressure
- Convert liquid agent to gas
- Deliver in a controlled manner

Functions (con’t)

- Provide positive pressure for ventilation
- Alert the provider to malfunction
- Prevent delivery of a hypoxic mixture

Components of the Machine

- Source gases
- Vaporizers
- Circuit
- Ventilator
- Scavenging system

Safety Standards

- 1979 -- Standards set for all machines sold in the U.S.
- ANSI -- (American National Standards Institute)
  - Released 1979 standards

Safety Standards (con't)

- ASTM -- (American Society for Testing and Materials)
  - Upgraded standards in 1988

The Generic Machine

- 2 sources of gas
  - Pipeline 50 psig
  - Tanks
    - »Oxygen: 2200 psig
    - »Nitrous oxide: 745 psig
    - »Both reduced to 45 psig upon entering the machine

The Generic Machine (con’t)

- Fail safe system (OFPD)
  - Stops flow if O_2 supply is lost
- Oxygen supply pressure alarm
- Second stage regulators
  - Reduces pressure to 14 psig

The Generic Machine (con’t)

- Flow control valves
  - Regulate gas flow
  - Separates high and low pressure circuits
- Common manifold

The Generic Machine (con’t)

- Vaporizer
- Outlet check valve
- Oxygen flush valve

Gas Sources

- Oxygen analysis is always required
- Pipeline
  - Enter at 50 psig
  - Gauge is on source side
  - DISS (Diameter Index Safety System)
    - »prevents gas swap

Gas Sources (con't)

- Side tanks
  - Usually E cylinders
    - Know pressure and volumes
  - Enter at 45 psig
  - Should be off unless in emergency use
    - Prevents silent emptying

Gas Sources (con't)

- Pin index safety system
  - Prevents tank swaps

    Pin positions

      Air 1-5

      Oxygen 2-5

      Nitrous oxide 3-5

Gas Sources (con't)

- Machine will use pipeline gas unless supply pressure drops below 45 psig

Fail Safe Devices

- Required by standards
- Stop flow of other gases if oxygen flow is interrupted
- Types
  - Threshold
  - Proportioning

Proportioning Systems

- Prevent delivery of less than 25% oxygen
- Either mechanical or pneumatic interface

Ohmeda Link-25 Proportion System

- Chain connects O_2 and N_2O flow control valves
- As N_2O is increased, the chain will turn O_2 control to maintain at least 25% O2. Oxygen is <u>increased</u>

Ohmeda Link-25
Proportion System (con’t)

- Maintains 3:1 ratio with combination of mechanical and pneumatic

Drager ORMC

- Pneumatic N_2O interlock
- Mobile shaft
- Slave control valve
- Pressure moves shaft and opens or closes slave valve

Drager ORMC (con't)

- N_2O flow is <u>reduced</u> to maintain 25% O_2
- Electrical contact provides alarm
  - Functional only in the O_2 / N_2O mode (not in the "all gases" mode)

Limitations of Proportioning Systems

- Wrong gas supply
- Defective operation
- Leaks downstream
- Inert gas administration

Flow Meter Assembly

- Controls and measures gas flow
- Thorpe tubes are tapered
- Indicator float is calibrated for specific tube
  - Density and viscosity differ
- Gas flows around float
  - Annular space

Flow Meter Standards

- Oxygen flow control knob
  - Physically different
  - Larger and projects further
  - Different shape
- All knobs are color coded
- Knobs are protected

Flow Meter Standards (con't)

- Low flow tubes for O_2 and N_2O
- Color coded flow tubes
- Thorpe tubes protected
- Tubes are <u>not</u> interchangeable
  - Float, tube and scale are single unit

Flow Meter Standards (con't)

- <u>Note</u>: Flow meters are located downstream from all safety devices except the oxygen analyzer.

Leaks

- Cracked tubes
- Faulty connections
- May create hypoxic mixture
- Oxygen is <u>always</u> downstream from other gases

Vaporizers

- Convert liquid anesthetic into a volatile inhalation agent
- Based on laws of physics
- You must memorize the chemical properties of the volatile agents

Applied Physics

- Vapor pressure
  - Dalton's law
  - Based on characteristics of agent
  - Varies with temperature

Applied Physics (con't)

- Boiling point
  - Vapor pressure equals atmospheric pressure
- Latent heat of vaporization
  - Heat required to change liquid into a vapor
  - Comes from liquid and environment

Types of Vaporizers

- Historic
  - Copper kettle
  - Vernitrol
- Modern
  - Ohmeda Tec 4
  - Drager Vapor 19.1

Ohmeda and Drager Characteristics

- Variable bypass
- Flow over
- Temperature compensated
- Agent specific
- Out of circuit

Copper Kettle and Vernitrol

- Measured flow
- Bubble through
- Non temperature compensated
- Multiple agent
- Out of circuit

Basic Design

- Gas enters vaporizer
- Flow is split
  - Majority is bypassed
  - Some enters vaporizing chamber
- Saturated gas leaves chamber
- Diluted by bypass gas
- Delivered to patient

Factors that Effect Output

- **Flow rate**
  - Accurate at most flows
  - Lower than dial setting at both extremes of flow
- **Temperature**
  - Vapor pressure varies with temp
  - Accurate at 20 - 35º C

Factors Effecting Output (con't)

- **Intermittent back pressure**
  - Retrograde flow
  - Higher than dial setting
    - » especially at low flows and high ventilator pressures
- **Carrier gas composition**
  - N_2O causes transient drop

Vaporizer Interlock System

- Only 1 vaporizer can be turned on
- Gas enters only the “on” vaporizer
- Leak of trace gas is minimized
- Vaporizers are locked into the circuit

Vapor Pressures:

Isoflurane - 238

Enflurane - 175

Halothane - 241

Desflurane

- Requires special vaporizer
  - Vapor pressure 664
  - Pressurized, heated chamber
    - »1550 mm / Hg prevents boiling

Vaporizer Hazards

- Misfilling
- Tipping
- Dual vaporizers on
- Leaks
- Free standing vaporizers

Misfilling

- Vaporizers are calibrated according to the vapor pressure of the agent
- If you fill with an agent with a higher v.p. -- overdose
- If you fill with an agent with a lower v.p. -- underdose

Anesthesia Circuits

Anesthesia Circuits

- Link machine to patient
- Eliminate carbon dioxide
- Mapleson classification
  - Many circuits in use
  - Modified Mapleson still in use
  - Know the current applications of modified Mapleson circuits

Types of Circuits

- Basic circle system
- Mapleson Classification

Basic components needed for delivery of anesthetic gases

Delivery Systems

- Connection to patient
- Breathing tubing
- Unidirectional valves
- Breathing bag

Delivery Systems (Cont'd)

- Pop-off valve
- Carbon dioxide absorption
- Bacterial filter

Circle System

- Allows rebreathing of anesthetic gases
  - lower FGF rates
  - Less pollution
- Requires CO_2 absorption
- Conserves heat and humidity

Advantages of Circle System

- Highly efficient
- Minimal dead space
- Conserves heat and moisture
- Minimal pollution
- Disadvantage - many places to leak

Components of the Circle System

- Fresh gas source
- Unidirectional valves
- Inspiratory & expiratory tubing
- Y-piece connector

Circle System Components (Cont'd)

- APL valve
- Reservoir bag
- CO_2 absorber

Rules for Circle System

- Unidirectional valve must be between patient & bag on both sides
- FGF <u>cannot</u> enter between patient & expiratory valve

Rules for Circle System (Cont'd)

- APL <u>cannot</u> be located between patient & inspiratory valve

Variations of the Circle System

Four Basic Circuits

- Open
- Semi-open
- Semi-closed
- Closed

Open Systems

- Insufflation
  - blow anesthetic gas over face
  - no direct contact
  - no rebreathing of gases
  - ventilation cannot be controlled
  - unknown amount delivered

Open Systems

- Open drop anesthesia
  - gauze covered wire mask
  - anesthesia dripped
  - inhaled air passes through gauze & picks up anesthetic

Open Systems (Cont'd)

- Open drop anesthesia (cont'd)
  - concentration varies
  - re-breathing may occur
  - environmental pollution

Semi-open Systems

- Breathing system which entrains room air
- Self inflating resuscitator system

Semi-closed System

- Gas enters from machine
  - part leaves via scavenger
- Circle system
- Bain system

Closed System

- Only enough gas enters to meet metabolic needs
- Scavenger is closed
- Closed circle system
- To-and-fro system

Closed System Anesthesia

- Technique <u>not</u> commonly used
- APL is closed and only enough O_2 is added to meet metabolic needs
- Anesthetic added based on square root of time
- Conserves anesthetic gas an eliminates pollution

The Scavenger System

- Releases excess pressure from the system
- Prevents operating room pollution
- Gases leave through APL
- May put too much negative pressure on the system

Systems Overview

Open System

- No reservoir
- No rebreathing

Semi-open System

- Has reservoir
- No rebreathing

Semi-closed System

- Has reservoir
- partial rebreathing

Closed System

- Has reservoir
- Complete rebreathing

Mapleson Breathing Circuits

- Early pioneers developed their own delivery systems
- Mapleson classified types of breathing devices

Mapleson Breathing Circuits (Cont'd)

- Mapleson circuits fall into which type of system?
- See Morgan p. 26, Table 3-1

Mapleson A

- FGI near bag
- Breathing tubing
- Expiratory valve near mask
- Volume of breathing tube should be as great as the tidal volume

Mapleson A

- Spontaneous ventilation
- High FGF flushes tubing between breaths

Mapleson A (Cont'd)

- Using "pop-off" enables controlled ventilation but also causes CO_2 rebreathing
- Current use?

Mapleson B

- Similar to A with FGI near expiratory valve
- System fills with FGF
  - –inhaled by patient

Mapleson B (Cont'd)

- Exhaled gas forced out through expiratory valve
- Current use?

Mapleson C

- Similar to Mapleson B
- Shorter breathing tubing
  - less dead space
- Current use?

Mapleson D

- Long breathing tube
- FGI near mask
- Exhalation valve at distal end of breathing tubing
- Current use?

Bain Breathing Circuit

- Modified Mapleson D
- Tube within a tube
  - FGF tube within larger tube
- Mounts on anesthesia machine
- APL valve
- Connects to scavenger

Bain System

- Advantages
  - compact, easy to handle
  - warming of inspired gases
  - partial rebreathing improves humidification
  - APL controls system pressure
  - ability of scavenging

Bain System Flow Rates

- Spontaneous ventilation
  - 200-300 ml/kg/min
- Controlled ventilation
  - infants <10kg 2 l/m
  - 10 - 50 kg 3.5 l/m
  - > 60 kg 70 ml/kg/min

Bain System

- Depends on fresh gas flow to flush out CO_2
- Spontaneous ventilation

  200 - 300 ml / kg / min
- Controlled ventilation

  70 ml / kg / min

Mapleson E

- Exhalation tube is reservoir
  - no bag
- FGI near mask
- Current use?

Mapleson F

- FGI near mask
- Breathing tubing/bag
- Expiratory valve at end of bag
- Current use?

Need To Know:

- Basic components
- Letters and names of systems currently in use
- Bain system
  - flow rates

Carbon Dioxide Absorption

- Allows rebreathing of anesthetic gases
- Review formulas from Chem / Physics
  - Know for Board exam

CO_2 Absorption (con't)

- Soda lime
  - 94% calcium hydroxide
  - 5% sodium hydroxide
  - 1% potassium hydroxide
  - silica to harden granules
  - ethyl violet as an indicator

CO_2 Absorption (con't)

- Baralime
  - 80% calcium hydroxide
  - 20% barium hydroxide
  - ethyl violet as an indicator

CO_2 Absorption (con't)

- pH is extremely high
- Granule size
  - 4 8 mesh
- Water is required for chemical reactions to occur

CO_2 Absorber Incompatibility

- Trichlorethylene
  - dichloroacetylene
    - neurotoxin
  - Phosgene
    - pulmonary irritant
- Sevoflurane
    - degrades in absorber

Ventilators Classified by:

- Power source
  - pneumatic
  - electric
  - both
- Drive mechanism
  - double circuit
  - driven by oxygen

Ventilator Classification (con't)

- Cycling mechanism
  - time cycled
  - pressure cycled
- Bellows classification
  - ascending / descending
    - »related to expiratory phase
  - Ascending is safer

Specific Ventilators

- Review reading assignment
- Do not memorize technical data
- Note similarities and differences

Ventilator Problems

- Circuit disconnect
  - Redundant alarms in place
  - Check APL valve
- Occlusion
- Barotrauma

Ventilator Problems (con’t)

- Leak in bellows assembly
- Mechanical problems
- Electrical problems

Setting the Ventilator
(Things your mama didn't tell you)

Based on the principle that $PaCO_2$ is directly proportional to alveolar ventilation

$$AV \times CO_2 = AV \times CO_2$$

(what you have) (what you want)

AV = alveolar ventilation

CO_2 = carbon dioxide

If you know 3, you can solve for the 4th

Patient weighs 150 lbs

R	10	20
TV	1000	500
MV	10,000	10,000
CO_2	40	??

Alveolar Ventilation

- Minute ventilation minus dead space
- Dead space = 1 cc / lb

Ventilator Settings

- If rate is constant, then dead space is constant
- If you <u>do not</u> change the rate,

  V_t X CO_2 = X CO_2

- You have R = 8, V_t = 650, $ETCO_2$ = 40. You want $ETCO_2$ = 33 and decide to leave the rate at 8. What new V_t is required to lower the $ETCO_2$ to 33?

$V_t \times CO_2 = V_t \times CO_2$

650 X 40 = ?? X 33

New TV = 788

Round off to 800 cc

Important concept

- PaCO2 is directly proportional to alveolar ventilation
- If dead space is constant, alveolar ventilation is directly proportional to tidal volume.

Humidification

- Which takes more energy?
  - –Humidification of dry gas
  - –Heating cold gas

Humidifying a dry gas takes more energy than heating cold gas.

The Artificial Nose (Humidity Trap)

- Provides external heat and humidity
- More effective

Heated Humidifier

- More dangerous
  - Larger circuit volume
  - Increased circuit compliance
  - Thermal injuries

The Anesthesia Machine Check

- Required standard of care
- You are responsible for the function of your machine
- Follow the checklist

Machine Check (con't)

- Document "machine checked"
- Don't cut corners
  - –Full check to start each day
  - –Abbreviated check between cases

American Express Items

(Don't leave home without them)

Oxygen

Positive Pressure

Suction